INVESTIGATION OF VIABILITY INDEXES OF THE COMMON REED'S SEEDS FROM WATER-BODIES WITH DIFFERENT LEVEL OF RADIONUCLIDE CONTAMINATION

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Abstract: Results of the common reed's seeds biological characteristics research in long-term radiation exposure conditions are represented. Dose relationships between liability indexes and abnormalities frequency of germs in water bodies with different levels of radionuclide contamination are indicated. High abnormalities percent and reduced liability indexes of common reed's seed progeny in water bodies with heightened level of dose rate are defined.

1. INTRODUCTION

Complicated radioecological situation in Ukraine after Chernobyl NPP (ChNPP) disaster occurred in 1986, requires systematic and long-time monitoring of remote effects of ionizing radiation on biological characteristics of living organisms [1, 2]. After Chernobyl disaster radionuclide contamination covered vast settled areas, first of all within Byelorussia, Ukraine and Russian Federation. Nowadays terrestrial and aquatic ecosystems are affected mostly by long-term ionizing radiation that is why it is important to study long-term radiation effects on living organisms. It is necessary to develop and implement the complex monitoring of ecosystems radioecological state within Chernobyl Accident Exclusion Zone. Special attention should be focused on fresh-water ecosystems as effective "accumulators" of the majority of long-lived and biologically-dangerous radionuclides. Aquatic-plant communities are an integral part of fresh-water ecosystems, early ontogenesis is one of life-cycle periods, most vulnerable to ionizing radiation exposure. Therefore radiation impact on seeds germination and germs growth should be investigated. Such studies may be valuable for prevention of negative consequences of ionizing radiation impact on fresh-water ecosystems and make some contribution to solving a problem of economic use of lands and water-bodies objects, contaminated as a result of the Chernobyl disaster [3]. The main aim of our research is to investigate peculiarities of the common reed's response on long-term ionizing radiation impact by means of liability indexes and germination processes investigation.

2. MATERIALS AND METHODS

2.1 Object and methodologies of research

For assessment of long-term ionizing radiation effects, seeds of the common reed (*Phragmites australis* (Trin) Ex. Steud) of 2009 year of vegetation were sampled. Common reed is a widespread air-aquatic plant which is either dominant or subdominant species of the littoral within the Chernobyl Accident Exclusion Zone. Seeds of the common reed are ellipse-shaped grains of 1.0-1.5 mm length and 0.4-0.6 mm width. Colour of seeds is brown-yellow or light-brown [4].

Liveability, germination indexes of the common reed's seeds and abnormalities percent of the common reed's germs were investigated in conditions of laboratorial cultivating [5].

Research was carried out with the help of methodology of absorbed dose rate assessment with dose conversion coeffecients (DCC) use [6]. Correlation analysis was carried out according to [7, 8].

Seeds of the common reed for research were taken from water bodies with different levels of radioactive contamination. Common reed's seeds were sampled from polygon water bodies of the left-bank floodplain of the Prypiat River – Glyboke and Daleke lakes; and right-bank floodplain – Azbuchyn Lake, Yanivsky Creek and Cooling Pond of the ChNPP. For comparison seeds were sampled from water bodies with background level of radioactive contamination – Kyiv water reservoir near Lyutizh village and Verbne Lake, located within Obolon residential district of the Kyiv city.

2.2 Absorbed dose rate assessment

As it is known, in conditions of radiation impact all living organisms and particularly plants receive dose from both internal and external sources of irradiation

Internal dose rate was calculated with the use of the following formula:

$$D_{\text{int}} = \sum_i C_i^{\text{int}} \times DCC_{\text{int},i}, \qquad (1)$$

where: C_i^{int} is the average specific activity of radionuclide i in the common reed's tissues (Bq kg^{-1} of raw mass);

$DCC_{int,i}$ is the dose conversion coefficient for internal exposure, determined as the ratio between the average specific activity of radionuclide *i* in investigated organism and absorbed dose rate to the organism (μGy hour^{-1} Bq kg^{-1}).

Basic formula for calculation of the external dose rate (radionuclides in water environment and background sources) was used:

$$D_{ext} = \sum_i C_i^{wat} \times DCC_{ext,i} + D_{bkg}, \qquad (2)$$

where: C_i^{wat} is the average specific activity of radionuclide *i* in aquatic environment (Bq l^{-1} of dissolved fraction);

$DCC_{ext,i}$ is dose conversion coefficient for external dose rate assessment, determined the ratio between average specific activity of radionuclide *i* in the environment (water, bottom sediments) and absorbed dose rate to the organism (μGy hour^{-1} Bq kg^{-1});

D_{bkg} is the absorbed dose rate from background sources (μGy hour^{-1}).

The total absorbed dose rate was defined as the sum of internal and external dose rates:

$$D_{total} = D_{ext} + D_{\mathrm{int}}, \qquad (3)$$

where: D_{total} is the total absorbed dose rate (μGy $hour^{-1}$);
D_{ext} is the external dose rate (μGy $hour^{-1}$);
D_{int} is the internal dose rate (μGy $hour^{-1}$).

2.3 Liability indexes and abnormalities investigation

The process of generative reproduction of plants is one of the most radiosensitive ontogenesis periods [5]. Seeds are convenient object for investigation of radiation exposure effects on reproductive ability of higher plants. Laboratorial cultivating of seeds is an effective testing system for assessment of their survivability, indication of abnormalities, and investigation of higher plants' ability to resist different additional effects [5]. Common reed's seeds for cultivation were planted on wet filtering paper in the Petri dishes. Seeds germinated in conditions of 5-10 kLx and 20-24 °C. Experiment lasted one month.

Three livability indexes were investigated: technical germinating ability, germinating power of seeds and survivability of germs.

Technical germinating ability B was calculated with the help of the following formula:

$$B = \frac{n \cdot 100}{N}, \qquad (4)$$

where: n is the number of germs, N is number of planted seeds.

Following formula was used for calculation of germinating power Egerm:

$$\AA_{germ} = \frac{n_{third} \cdot 100}{N}, \qquad (5)$$

where: n_{third} is the number of germs appeared at one third of the experiment period, N – number of planted seeds.

Survivability of germs S was calculated with the use of the formula:

$$S = \frac{N_{surv} \cdot 100}{N_{germ}}, \qquad (6)$$

where: N_{surv} is the number of survived germs, N_{germ} is the number of germs.

Speed of leafs and roots growth is an important indicator for assessment of ontogenesis damage [5].

Following formula was used for analysis of roots and leafs speed growth:

$$S_p = \frac{L_{av}}{D}, \qquad (7)$$

where: S_p is the speed of leafs and roots growth; L_{av} is the average length of roots and leafs; D is a day of experiment.

Different groups of germs abnormalities were investigated. Specific group of them is so called chlorophyll or pigment abnormalities. Germs often have such abnormalities as "curled" hypocotile, roots, leaves or whole body, to the extent disturbance of normal geotropism [5]. Another frequent type of abnormalities is necroses of the roots and cotyledons of germs. Growth abnormalities are ones of significant group. They were defined as summary

number of germs with more than one root growing from the common base, number of germs with roots growing from different points and number of germs without root.

Abnormalities number was assessed with the use of the following formula:

$$A = \frac{N_{abnrm} \cdot 100}{N}, \tag{8}$$

where: N_{abnrm} is the number of germs with abnormalities of certain group, N is the number of planted seeds.

3. RESULTS

3.1 Absorbed dose rate

Absorbed dose rate in the most radionuclide contaminated Glyboke and Daleke lakes was significantly higher than in water bodies of right-bank floodplain of the Prypiat River. Calculated absorbed dose rate values for the common reed in investigated water bodies were in following ranges: 7.9-16.0 cGy year^{-1} and 3.4-7.1 cGy year^{-1} – in Glyboke and Daleke lakes correspondingly, 1.7-7.2 cGy year^{-1}, 1.6-5.7 cGy year^{-1} and 1.3-3.1 cGy year^{-1} – in Azbuchyn Lake, Yanivsky Creek and Cooling Pond of the ChNPP correspondingly. The lowest absorbed dose rate was calculated for plants from Kyiv reservoir near Lyutizh village and Verbne Lake (Obolon residential district of the Kyiv city) – 0.1-0.4 cGy year^{-1} and 0.01-0.04 cGy year^{-1} – correspondingly.

3.2 Liveability and germination indexes

In conditions of the common reed's seeds laboratorial cultivation, enormous delay of the last germ emergence in comparison with first one was indicated in the most radionuclide contaminated water bodies of Chernobyl Accident Exclusion Zone. First germ appeared at second day of experiment in all water bodies. In polygon water bodies last germ appeared at nineteenth day (Yanivsky Creek, Cooling Pond of the ChNPP) and twenty sixth day (Glyboke, Daleke and Azbuchun lakes) in contrast to water bodies with background level of radionuclide contamination (Kyiv Reservoir (near Lyutizh village) and Verbne Lake – at ninth day).

Normal indexes of liability – technical germinating ability, germinating energy and survivability were registered in water bodies with background level of radionuclide contamination – Kyiv Reservoir (near Lyutizh village) – 83, 87 and 49 % correspondingly and Verbne Lake within Obolon residential district of the Kyiv city – 93, 91 and 54 % correspondingly. However, investigated indexes were significantly lower in the polygon water bodies – Glyboke Lake (60, 31 and 38 % correspondingly), Daleke Lake (59, 49 and 35 % correspondingly), Azbuchyn Lake (67, 47 and 42 % correspondingly), Yanivsky Creek (55, 46 and 37 % correspondingly) and Cooling Pond of the ChNPP (73, 57 and 55 % correspondingly).

Analysis of livability indexes – technical germinating ability, germinating energy and survivability (fig. 1) helped to indicate inverse dose dependence of

them.

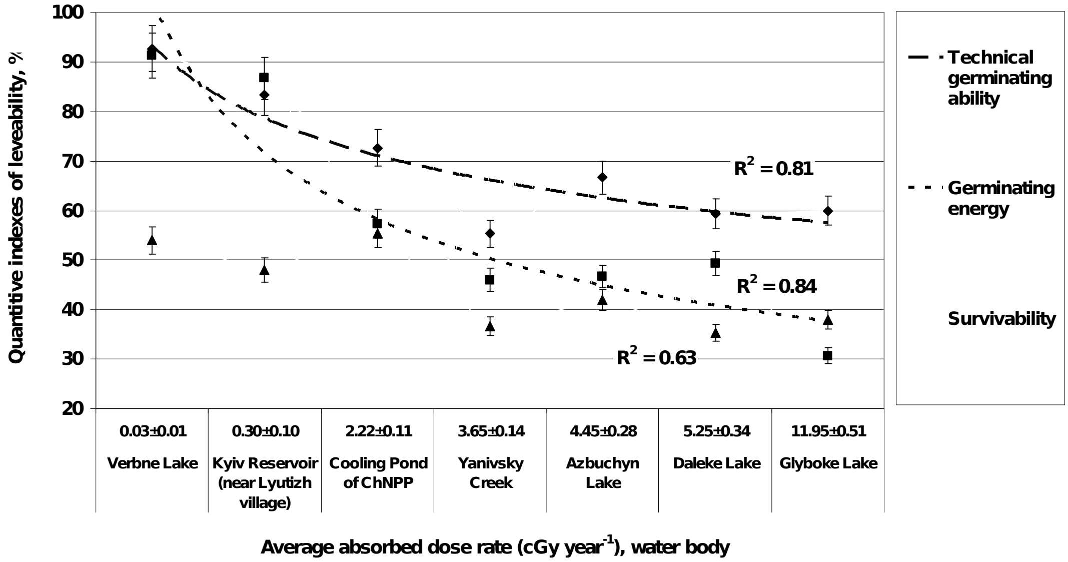

Fig. 1. Dose dependence of livability indexes of the common reed's seeds at different levels of radionuclide contamination of water bodies

Negative correlation between total absorbed dose rate and indexes of technical germinating ability (r = -0.637), germinating energy (r = -0.833) and survivability (-0.639) was indicated

Results of leafs and roots growth speed investigation (fig. 2) testify about growth speed differences in water bodies with background and heightened levels of radionuclide contamination.

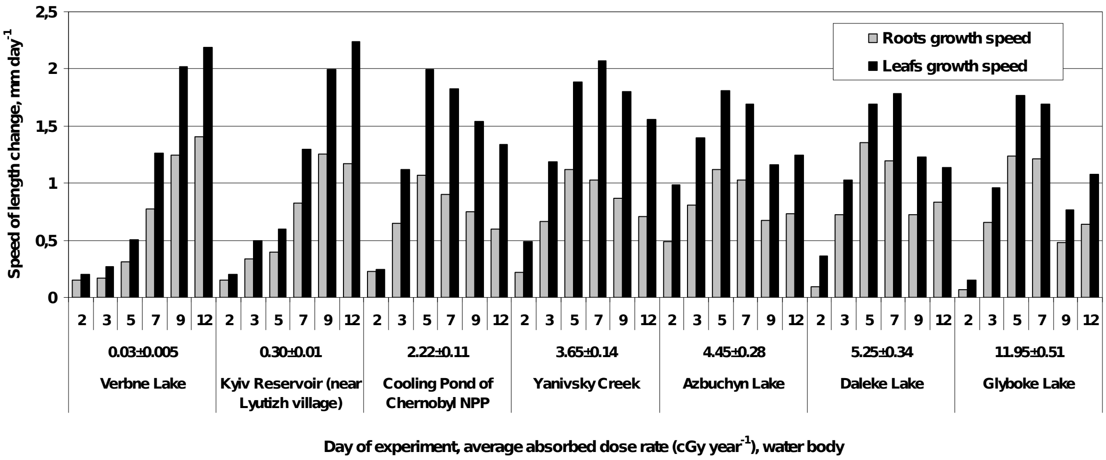

Fig. 2. Roots and leafs growth speed in water bodies within the Chernobyl Accident Exclusion Zone and water bodies with background level of radionuclide contamination

Rapid increase of the leafs and roots growth speed in water bodies with background level of radionuclide contamination – Verbne Lake (0.2-1.4 and 0.2-2.2 mm day^{-1} correspondingly) and Kyiv Reservoir (near Lytizh village) – 0.2-1.3 and 0.2-2.3 mm day^{-1} correspondingly, was registered during first twelve days of experiment. In polygon water bodies speed of both root and leaf growth

significantly differed. The highest speed of roots growth was registered in all polygon water bodies only at fifth day (1.1-1.4 mm day^{-1}). After fifth day roots growth descent was registered – up to 0.6-0.8 mm day^{-1}. In polygon water bodies leafs grew with the highest speed at 5-7th day of experiment (1.7-2.1 mm day^{-1}). After significant increase, leafs growth speed lowered up to 0.8-1.6 mm day^{-1}.

3.3 Abnormalities

High percent of germs abnormalities of different groups in the most radioactive contaminated water bodies of the Chernobyl Accident Exclusion Zone was indicated (table).

Table. Different types abnormalities of the common reed's germs in water bodies with different levels of radionuclide contamination

Water-body	Dose rate interval, cGy $year^{-1}$	Abnormalities, %				Norm, %
		Root necroses	Geotropism disturbances	Ontogenesis disturbances	Chlorophyllic abnormalities	
Glyboke Lake	7.9-16	8.67	16.00	24.00	0.00	51.33
Deleke Lake	3.4-7.1	14.67	14.67	38.00	1.33	31.33
Azbuchyn Lake	1.7-7.2	12.67	9.33	28.00	2.00	48.00
Yanivsky Creek	1.6-5.7	4.00	8.00	32.67	1.33	54.00
Cooling Pond of ChNPP	1.3-3.1	4.00	5.33	22.00	1.33	67.33
Kyiv Reservoir (near Lyutizh village)	0.1 - 0.4	4.00	4.00	6.00	0.00	86.00
Verbne Lake	0.01 - 0.04	1.33	2.67	4.00	0.00	92.00

High total percent of germs abnormalities in the most radioactive contaminated water bodies of the Chernobyl Accident Exclusion Zone (69, 52 and 49 % – Daleke, Azbuchyn and Glyboke lakes correspondingly) relatively to water bodies with background level of radionuclide contamination (14, 8 % – Kyiv Reservoir (near Lyutizh village) and Verbne Lake correspondingly) was determined. Correlation dependence between average absorbed dose rate and root necroses (r = 0.535), ontogenesis disturbances (r = 0.532) and geotropism disturbances (r = 0.907) was calculated.

4. CONCLUSIONS

Reliable decrease of liability indexes (germinating ability, germinating energy and survivability) of the common reed's seed progeny in water bodies with heightened level of radioactive contamination was indicated.

Analysis of roots and leafs growth speed of the common reed's germs denotes significant disturbances during plants ontogenesis in water bodies where total absorbed dose rate varies in range 1-12 cGy $year^{-1}$.

Low liability and extremely high abnormalities percent (up to 70 %) of the

common reed’s germs were defined in water bodies of the most contaminated part of left-bank of the Prypiat River floodplain.

Power dose dependences of seeds liability indexes, correlation dependence between total absorbed dose rate and abnormalities of germs development were determined.

Research results may be recommended for use in the complex radioecological monitoring of radioactive contaminated aquatic ecosystems, radiation risks assessment, as well as implementation and improvement of radiation protection measures.

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